SIMULTANEOUS MULTI-SLAB ACQUISITION IN 3D MULTI-SLAB DIFFUSION-WEIGHTED READOUT-SEGMENTED ECHO-PLANAR IMAGING

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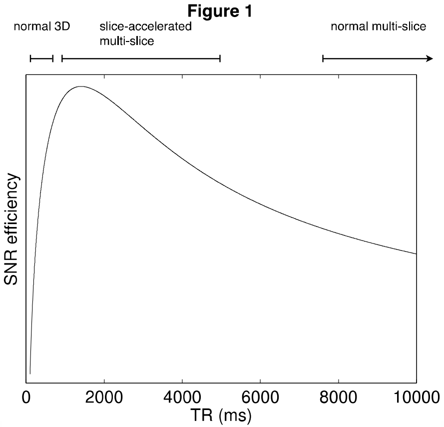
Introduction Diffusion-weighted (DW) readout-segmented EPI (rs-EPI) (1-4) uses segmentation of *k*-space in the readout (k_x) direction over multiple TRs to reduce geometric distortion and T2* blurring compared to single-shot EPI (ss-EPI). As originally implemented, the need for multiple TRs increases scan time, roughly by the number of readout segments. Scan time reductions for rs-EPI have been demonstrated by: 1) using partial Fourier techniques to reduce the number of TR periods (5) and 2) reducing TR with a simultaneous multi-slice acquisition (6). In another abstract, we present a novel 3D multi-slab version of rs-EPI (7) that aims to enable SNR-optimal TRs of 1-2s, but this can at present only be achieved with limited brain coverage. In this abstract, we accelerate our 3D rs-EPI technique by extending simultaneous multi-slice methods (8,9) to a 3D, multi-slab acquisition. Multiple slabs are excited simultaneously and k_z phase-encoded together before data from each k_z partition is un-aliased in *k*-space. This simultaneous multi-slab approach enables whole-brain coverage in the SNR-optimal TR range of 1-2s as shown in Fig. 1. The plot in Fig. 1 was generated using Bloch simulations of spin-echo signal with white matter tissue T_1=1000 ms and T_2=75ms.

Figure 1



Methods The simultaneous multi-slab method was applied to a novel 3D multi-slab rs-EPI sequence, which is described in detail elsewhere (7). Briefly, rs-EPI is extended to 3D with a simple *z* phase encoding to acquire both the high-resolution imaging data and navigator as 2D k_z planes. This scheme is sufficient for navigator motion correction, provided the slabs are not too thick. The *k*-space acquisition is synchronized to the cardiac cycle in real time using a pulse oximeter to determine which segment to acquire (2,10). This scheme acquires low-corruption data at the centre of *k*-space and minimizes discontinuities and periodicity across *k*-space, reducing motion phase artefacts by 40-50%. Data were acquired with both multi-slab and in-plane accelerations. A multiband RF pulse (phase-modulated sum) simultaneously excited *R*=2 slabs with slab separation *S*. Blipped-CAIPI slice gradients (9) for reducing g-factor SNR loss were not used. The GRAPPA kernel used to separate slab data is calculated from reference data with single-slice excitation (b=0). The slice-GRAPPA reconstruction (9) uses separate kernels for each partition of each slab (calculated from a full *k*-space acquisition of the multiband b=0 and single-slice reference data). The full reconstruction pipeline was phase-correction, regridding, slice-GRAPPA unaliasing, in-plane GRAPPA (11) (acceleration R_{PE}), non-linear navigator correction, segment concatenation and sum-of-squares coil combination. Artefacts at the interfaces between slabs were improved with a combination of slab overlap, k_z oversampling and interleaving of odd and even slabs in separate concatenations. The simultaneous multi-slab acquisition is illustrated in Fig. 2.

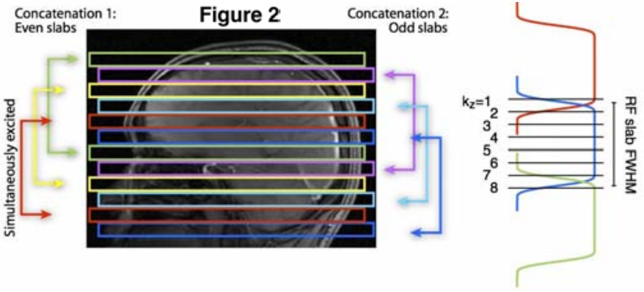
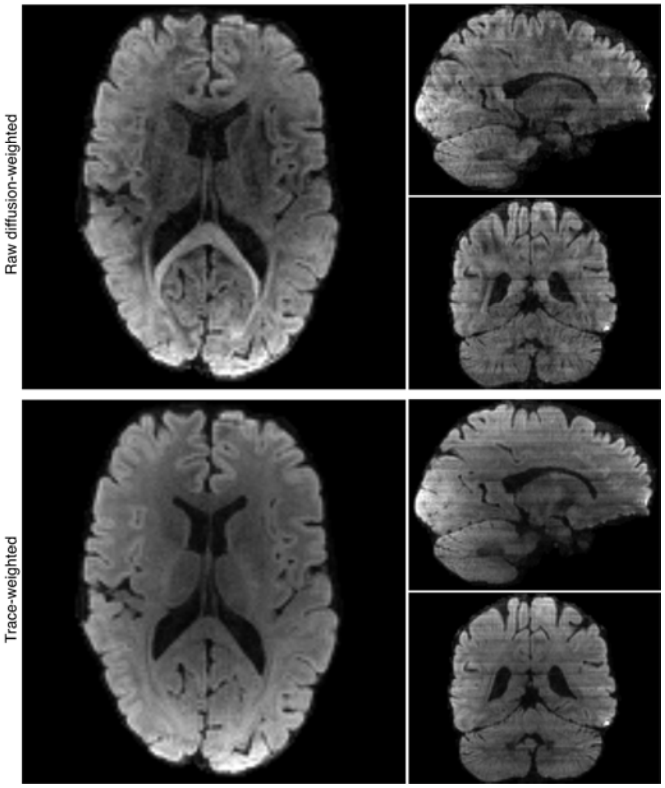


Figure 2

Experiments Data were acquired using a 32-channel receive coil on a standard commercial 3T system and diffusion weighting was achieved with a modified Stejskal-Tanner preparation. Navigator-based reacquisition (utilized in the standard 2D sequence) was not used at this stage due to incompatibility with the existing real-time reconstruction. A 1.5mm isotropic simultaneous multi-slab 3D rs-EPI protocol for trace-weighted imaging was acquired with the following parameters: FOV=220×220mm^2; matrix=144×144; 7 readout segments; R_{PE}=2; TR/TE=1500/75ms; α=77°; 8 slabs with 25% slab overlap, 8 k_z partitions within each slab with 10% k_z oversampling; *S*=72mm; three b=1000s/mm^2 directions and one volume without diffusion-weighting; scan time=11:30min for full *k*-space acquisition plus 2:50min for each of the two reference acquisitions. Brain extraction was performed using FSL (12).

Results & Discussion Raw DW and trace-weighted images are shown in Fig. 3. The simultaneous multi-slab acceleration allows full brain coverage in an SNR-optimal TR=1.5s. In this study full *k*-space reference data were used to improve the estimation of the slice-GRAPPA weights; however the amount of data required in the reference acquisition could be reduced by further optimisation of the method. Also, relative in-plane shifting of simultaneously acquired data from separate slabs with blipped-CAIPI gradients (9) could be used to improve SNR in the reconstruction. Blipped-CAIPI, reacquisition and improvements to slab-joining artefacts are the subject of ongoing work. To reduce scan time, we will explore higher slab-acceleration factors and fewer readout-segments with partial Fourier (5).

Figure 3



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References (1) Robson MRM 1997. (2) Miller MRM 2003. (3) Nguyen ISMRM 1998. (4) Porter MRM 2009. (5) Frost MRM 2012. (6) Frost ISMRM 2012 (7) Frost submitted to ISMRM 2013. (8) Larkman JMRI 2001. (9) Setsompop MRM 2011. (10) Tijssen NImg 2011. (11) Griswold MRM 2002. (12) Jenkinson NImg 2012.